Current Research

Evaluation of the Healthy Eating Index-2005

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ABSTRACT

Background The Healthy Eating Index (HEI), a measure of diet quality as specified by federal dietary guidance, was revised to conform to the Dietary Guidelines for Americans 2005. The HEI has several components, the scores of which are totaled.

Objective The validity and reliability of the HEI-2005 were evaluated.

Design Validity was assessed by answering four questions: Does the HEI-2005 1) give maximum scores to menus developed by experts; 2) distinguish between groups with known differences in diet quality—smokers and nonsmokers; 3) measure diet quality independently of energy intake, a proxy for diet quantity; and 4) have more than one underlying dimension? The relevant type of reliability, internal consistency, was also assessed.

Subjects Twenty-four–hour recalls from 8,650 participants, aged 2 years and older, in the National Health and Nutrition Examination Survey, 2001-2002 were analyzed to answer questions 2 to 4. Results were weighted to consider sample design and nonresponse.

Statistical analyses *T* tests determined differences in scores between smokers and nonsmokers. Pearson correlation coefficients determined the relationship between energy intake and scores. Principal components analysis determined the number of factors that comprise the HEI-2005. Cronbach's coefficient α tested internal consistency.

Results HEI-2005 scores are at or very near the maximum levels for all sets of exemplary menus with one exception; the Harvard menus scored low on the milk component because these menus intentionally include only small amounts of milk products. Nine of 12 component scores were lower for smokers than nonsmokers. The correlations of component scores were virtually independent of energy intake ($< |.22|$). Multiple factors underlie the HEI-2005. Coefficient α was .43. The α value for all tests was .01.

Conclusions The HEI-2005 is a valid measure of diet quality. Potential uses include population monitoring, evaluation of interventions, and research. The individual component scores provide essential information in addition to that provided by the total score.

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The Dietary Guidelines for Americans are the basis of nutrition policy for the United States Government and the foundation of all federal nutrition guidance (1). The United States Department of Agriculture's (USDA) Center for Nutrition Policy and Promotion developed a Healthy Eating Index (HEI) to measure compliance with dietary guidance in 1995 and modified it slightly since then (2-5). The HEI is used by the USDA to monitor change in the nation's diet (6).

The USDA's HEI was recently revised to reflect the 2005 Dietary Guidelines, and a new scoring system was developed (7). The components of the Healthy Eating Index-2005 (HEI-2005) represent all of the major food groups found in MyPyramid (8)—total fruit; total vegetables; total grains; milk, which includes soy beverages; and meat and beans, which includes meat, poultry, fish, eggs, soybean products other than beverages, nuts, seeds, and legumes. Additional components represent whole fruit (ie, forms other than juice); dark green and orange vegetables and legumes; whole grains; oils (nonhydrogenated vegetable oils and oils in fish, nuts, and seeds); saturated fat; sodium; and calories from solid fats, alcoholic beverages, and added sugars. A more detailed description of the HEI-2005 and its development is presented in a companion article (7). The purpose of this article is to evaluate the validity and reliability of the HEI-2005.

METHODS

The performance of the HEI-2005 was evaluated by assessing its validity and reliability as summarized in Figure 1. To do this, we scored 1-day dietary intakes obtained from a national sample and several sets of exemplary menus. The results from the HEI-2005 were compared with results from the original HEI for two of the analyses as described here.

Data Analysis

For all analyses, except the scoring of the menus, data from 8,650 respondents from the National Health and Nutrition

Property	Question	Strategy
Content validity	Does the index capture the various key aspects of diet quality specified in *Dietary Guidelines for Americans* 2005?	Checked HEI-2005 components against the Dietary Guidelines for Americans 2005
Construct validity	Does the index give maximum scores to menus developed by nutrition experts to illustrate high diet quality?	Computed scores for menus from MyPyramid, the DASH[a] Eating Plan, Harvard's Healthy Eating Pyramid, and American Heart Association's No-Fad Diet (Table 1)
	Does the index distinguish between groups with known differences in diet quality, ie, does it have concurrent criterion validity?	Compared scores of smokers and nonsmokers (Table 2)
	Does the index measure diet quality independent of diet quantity?	Estimated Pearson correlations between component scores and energy intake (Table 3)
	What is the underlying structure of the index components, ie, does it have more than one dimension?	Examined structure by using a principal components analysis (Figure 3)
Reliability	How reliable is the total index score if diet quality is found to have one dimension?	Determined Cronbach's coefficient α
	What are the relationships among the index components?	Estimated Pearson correlations among component scores (Table 3)
	Which components have the most influence on the total score?	Estimated correlations between each component and sum of all others (Table 3)

Figure 1. Strategies to evaluate the Healthy Eating Index-2005 (HEI-2005). [a]DASH=Dietary Approaches to Stop Hypertension.

Examination Survey, 2001-2002 (NHANES 2001-2002) were used. Children younger than the age of 2 years and breast-fed children were excluded because the Dietary Guidelines and MyPyramid were not designed to meet their needs. Pregnant and lactating women were excluded in accordance with practices for calculating original HEI population scores (3-5). Survey respondents provided one 24-hour recall of dietary intake, administered by an interviewer (9). Only individuals whose intake data were complete and reliable were included. Respondents who were fasting on the recalled day were assigned a score of zero for all HEI components. Sodium intake data in NHANES do not include salt added at the table.

All statistical analyses were conducted by using SAS (version 8.1, 1999-2000, SAS Institute, Inc, Cary, NC), except when standards errors were estimated. In that case, SUDAAN (version 9.0, SAS Institute, Inc, 2002) was used. The 2-year examination sampling weights were used to account for the survey design and nonresponse (9).

HEI-2005 scores were calculated for four sets of exemplary menus: the sample 7-day 2,000-calorie menu provided on the MyPyramid Web site (10); the sample 7-day menu for the Dietary Approaches to Stop Hypertension (DASH) Eating Plan, developed by the National Heart Lung and Blood Institute (11); the two 1-week sample menus for Harvard Medical School's Healthy Eating Pyramid (12); and the two 1-day sample menus from the American Heart Association's No-Fad Diet (13,14). Each menu item was coded by a registered dietitian using the Food Intake Analysis System (version 3.99, 1998, University of Texas-Houston School of Public Health, Houston, TX), which uses the USDA food coding system and, therefore, allowed the data to be linked to the MyPyramid Equivalents Database (version 1.0) and the NHANES nutrient data files. The registered dietitian created recipes and modification codes as needed.

To create the HEI-2005 scores, a density value was calculated for the daily intake of each food group and nutrient of interest. For example, the reported amount of a food group consumed was divided by the reported total energy and multiplied by 1,000. We then compared that density value with the standard established for the respective component and determined the score (7). The maximum scores for the components are 5, 10, or 20 points. A documented version of the SAS code used to create the HEI-2005 scores for NHANES 2001-2002 participants in this study can be found at http://www.cnpp.usda.gov/Publications/HEI/HEI-2005/HEI2005_NHANES0102.txt. For analyses using the original HEI, the scores calculated previously for NHANES 2001-2002 by the USDA Center for Nutrition Policy and Promotion were used (15).

Because the calculation of HEI-2005 scores involves ratios, the specific algorithm used depended on whether we were assigning values to 1-day intakes by individuals in NHANES or to a set of menus designed to represent an individual's intake over several days. Using the total grains component as an example, an individual's score based on a single day's intake was computed as follows:

$$(\mathrm{TG/E})^{*}1{,}000)_{\mathrm{individual}} \rightarrow \mathrm{Assign\ Score}_{\mathrm{individual}}$$

where TG=total grain intake for the day, and E=energy intake for the day. All of the component scores were then summed to get the individual's 1-day total HEI score.

In the case of the menus, scores were calculated by using the population ratio method, that is, by summing the appropriate dietary constituent over all the days,

Dietary Guidelines key recommendation	HEI-2005 component	Comment
Adequate nutrients within calorie needs		
• Consume a variety of nutrient-dense foods and beverages within and among the basic food groups while choosing foods that limit the intake of saturated and *trans* fats, cholesterol, added sugars, salt, and alcohol.	Fruit Total Whole Vegetables Total Dark green and orange Vegetables and legumes Grains Total Whole Milk Meat and beans Oils Saturated fat Sodium Calories from solid fats, alcoholic beverages, and added sugars	The HEI-2005 assesses intake of MyPyramid food groups and saturated fat directly. Solid fats, added sugars, and alcohol are represented in the calories from solid fats, alcoholic beverages, and added sugars component. *Trans* fats are reflected in solid fats; and, therefore, are also included in calories from solid fats, alcoholic beverages, and added sugars. Cholesterol is not included in the HEI-2005 per se. Salt is reflected in the sodium component.
• Meet recommended intakes within energy needs by adopting a balanced eating pattern, such as the US Department of Agriculture (USDA) Food Guide or the Dietary Approaches to Stop Hypertension (DASH) Eating Plan.	Fruit Vegetables Grains Milk Meat and beans Oils Calories from solid fats, alcoholic beverages, and added sugars	The HEI-2005 food group components and standards are based on the USDA Food Guide, now known as MyPyramid.
Weight management		
• To maintain body weight in a healthy range, balance calories from foods and beverages with calories expended. • To prevent gradual weight gain over time, make small decreases in food and beverage calories, and increase physical activity.		The HEI-2005 does not measure energy intake because it assesses quality rather than quantity of the diet. Indicators of healthy body weight, such as body mass index and waist circumference, could be used in conjunction with the HEI-2005 and would provide a very good indicator of long-run energy balance.
Physical activity		
• Engage in regular physical activity and reduce sedentary activities to promote health, psychological well-being, and a healthy body weight. • Achieve physical fitness by including cardiovascular conditioning, stretching exercises for flexibility, and resistance exercises or calisthenics for muscle strength and endurance.		The HEI-2005 does not include physical activity. Measures of physical activity could be used in conjunction with the HEI-2005.
Food groups to encourage		
• Consume a sufficient amount of fruits and vegetables while staying within energy needs.	Total fruit Total vegetables	The HEI-2005 standards for fruits and vegetables are based on MyPyramid recommendations.
• Choose a variety of fruits and vegetables each day. In particular, select from all five vegetable subgroups (dark green, orange, legumes, starchy vegetables, and other vegetables) several times a week.	Fruit Total Whole Vegetables Total Dark green, orange, legumes	Variety is specified. Whole fruits and particular subgroups of vegetables are emphasized because they tend to be lacking in diets.
• Consume 3 or more ounce-equivalents of whole-grain products per day, with the remainder of the recommended grains coming from enriched or whole-grain products. In general, at least half of the grains should come from whole grains.	Grains Total Whole	The standard for whole grains is 1.5 ounce equivalents per 1,000 calories, which is half the standard for total grains. The standard for total grains is 3 ounce equivalents per 1,000 calories.
• Consume 3 cups per day of fat-free or low-fat milk or equivalent milk products.	Milk	The standard for milk is 1.3 cup equivalents per 1,000 calories. Higher-fat milk products result in lower scores for the saturated fat and calories from solid fats, alcoholic beverages, and added sugars.

(continued)

Figure 2. Healthy Eating Index-2005 (HEI-2005) components mapped to 2005 Dietary Guidelines key recommendations.

Dietary Guidelines key recommendation	HEI-2005 component	Comment
Fats		
• Consume <10% of calories from saturated fat, <300 mg/day of cholesterol, and keep *trans* fatty acid consumption as low as possible.	Saturated fat Calories from solid fats, alcoholic beverages, and added sugars	The standard of 7% for saturated fat is <10% of calories. *Trans* fatty acids are reflected in solid fats. Cholesterol is not included because limiting saturated fat is considered more important and because intakes of total fat and cholesterol are correlated with it (7).
• Keep total fat intake between 20% and 35% of calories with most fats coming from sources of poly- and monounsaturated fatty acids, such as fish, nuts, and vegetables oils.	Oils Saturated fat Calories from solid fats, alcoholic beverages, and added sugars	Total fat is not included because limiting saturated fat is considered more important and because intakes of total fat are correlated with it (7). Poly- and monounsaturated fats are reflected in the oils component.
• When selecting and preparing meat, poultry, dry beans, milk or milk products, make choices that are lean, low-fat, or fat-free.	Saturated fat Calories from solid fats, alcoholic beverages, and added sugars	Excess fat from meat, poultry, and milk products is counted as solid fat and contributes to both the saturated fat and calories from solid fats, alcoholic beverages, and added sugars.
• Limit intake of fats and oils high in saturated and/or *trans* fats and choose products low in such fats and oils.	Saturated fat Calories from solid fats, alcoholic beverages, and added sugars	Saturated fat is a component. *Trans* fats are reflected in solid fats.
Salt, sodium, and potassium		
• Consume <2,300 mg (approximately 1 tsp salt) of sodium per day.	Sodium	The standard for the relatively good score of 8 is 1,100 mg per 1,000 calories, which is approximately 2,300 mg per 2,150 calories, the basis of the Tolerable Upper Intake Level set by the Food and Nutrition Board. The standard for the optimum score of 10 was based on the Adequate Intake (AI) for sodium.
• Choose and prepare foods with little salt. At the same time, consume potassium-rich foods, such as fruits and vegetables.	Sodium Total fruit Total vegetables	MyPyramid recommendations for fruit and vegetables were set, in part, to meet the AIs for potassium.
Alcoholic beverages		
• Those who choose to drink alcoholic beverages should do so sensibly and in moderation—defined as the consumption of up to one drink per day for women and up to two drinks per day for men.	Calories from solid fats, alcoholic beverages, and added sugars	Alcohol is considered in the calories from solid fats, alcoholic beverages, and added sugars component; however, it is not limited to the amounts specified in the Dietary Guidelines.
• Alcoholic beverages should not be consumed by some individuals, including those who cannot restrict their alcohol intake, women of childbearing age who may become pregnant, pregnant and lactating women, children and adolescents, individuals taking medications that can interact with alcohol, and those with specific medical conditions.		Calories from alcohol are counted the same for everyone.
• Alcoholic beverages should be avoided by individuals engaging in activities that require attention, skill, or coordination, such as driving or operating machinery.		Activities at the time of alcohol consumption are not considered.
Food safety		
• To avoid microbial foodborne illness - Clean hands, contact surfaces, and fruits and vegetables. Meat and poultry should not be washed. - Separate raw, cooked and ready-to-eat foods while shopping, preparing, or storing foods. - Cook foods to a safe temperature to kill microorganisms. - Chill (refrigerate) perishable food promptly and defrost foods properly. - Avoid raw (unpasteurized) milk or any products made from unpasteurized milk, raw or partially cooked eggs or foods containing raw eggs, raw or undercooked meat and poultry, unpasteurized juices and raw sprouts.		The HEI-2005 does not address food safety.

Figure 2. (Continued)

summing number of calories over all the days, dividing the total amount of the dietary constituent by the total number of calories, and comparing this ratio with the standard:

$$\frac{\Sigma(\mathrm{TG})_{\mathrm{day}}}{\Sigma(\mathrm{E})_{\mathrm{day}}} \rightarrow \text{Assign Score}_{\text{“individual”}}$$

where “individual” refers to the menu. The component scores were then summed to get the total HEI score.

Evaluation Plan

Content validity examines qualitatively the extent to which an index represents the variety of attributes that make up the intended domain—in this case, diet quality as specified by the 2005 Dietary Guidelines. To evaluate this, the set of components were checked against the key recommendations (1).

Construct validity evaluates quantitatively how well an index measures what it is supposed to measure, in this case, diet quality. The construct validity of the HEI-2005 was assessed in four ways. First, we looked at four sets of menus developed by other nutrition experts to represent very-high-quality diets and scored them by using the HEI-2005. The HEI-2005 component scores for each of the four sets of menus were calculated by using the population ratio method described here.

Second, we examined concurrent-criterion validity, another type of construct validity that evaluates whether the index can distinguish between groups with known differences in the quality of their diets. Because previous studies have shown that current smokers have poorer quality diets than do nonsmokers (16-19), we assessed the ability of the HEI to distinguish differences in diet quality in terms of average 1-day diet scores between these two groups of adults, age 20 years and older, using data from the NHANES 2001-2002. This analysis was conducted for both the HEI-2005 and the original HEI so that the relative ability of the two indexes to differentiate diet quality could be determined. Because of the large sample size, an α level of .01 was chosen to determine statistically significant differences.

Third, we determined whether the HEI-2005 could assess diet quality independent of diet quantity, as measured by the diet's energy value. Because nutrient intake is positively correlated with energy intake, a diet quality index could overrate high-calorie diets, especially if nutrient adequacy is weighted more heavily than is moderation and if intakes are measured in terms of absolute amounts rather than as densities. To evaluate this independence, the Pearson correlations of the HEI-2005 total and component scores with energy intake were examined and compared with those of the original HEI. Low correlations between energy and the scores would suggest independence.

Fourth, we examined the underlying structure of the index through principal components analysis (PCA) (20). Based on the correlations among the 12 components, the PCA was used to determine the number of independent factors that comprise the HEI-2005. The primary question was to determine whether there was one or more than one factor that accounted for the systematic variation observed in the data.

For both the original HEI and the HEI-2005, Cronbach's coefficient α was used to assess one form of reliability, internal consistency, which examines the degree of association among the components within an index. This statistic is mathematically equivalent to the average of the correlations among all possible split-half combinations of the 12 HEI-2005 components, and thus captures any systematic variation underlying the dietary components that are measured. To further understand the relationships among components, the inter-component correlations were examined. The coefficient α was expected to be low because diet quality is known to be a complex and multidimensional construct and because individuals do not consistently meet, or fail to meet, all the dietary standards used to assess diet quality. For example, a diet may meet the standard for meat and beans, but fail to meet the standard for whole fruit. Thus, internal consistency is not a necessary characteristic of the HEI, but it does have implications for its interpretation in various research applications. To see which components have the most influence on the total score, we examined the correlations of each of the components with the total score minus that component for both the HEI-2005 and the original HEI.

RESULTS

The results of the qualitative check of the HEI-2005 components against the key recommendations of the 2005 Dietary Guidelines are found in Figure 2. The key recommendations that relate to diet quality are captured by the index.

Not surprisingly, the HEI-2005 scores for the four exemplary sets of menus—based on MyPyramid, the DASH Eating Plan, Harvard's Healthy Eating Pyramid, and the American Heart Association's No-Fad Diet—were very high, as shown in Table 1. The Harvard menus scored full points for all the components except milk; this was expected because the Harvard food guide does not encourage the consumption of milk and milk products.

Differences in 1-day scores between smokers and nonsmokers for the HEI-2005 and the original HEI are shown in Table 2. Nine of the 12 HEI-2005 component scores were significantly lower ($P<0.01$) for the smokers, compared with the nonsmokers; exceptions were meat and beans, saturated fat, and sodium, for which no differences were found. Smokers' mean total HEI-2005 score (44.7) was significantly lower than nonsmokers' (53.3). With the original HEI, only five of the 10 individual component scores were significantly different. Smokers' mean total scores were also significantly lower than were nonsmokers', but by a narrower range.

The correlations between each of the HEI component scores and energy intake are found in Tables 3 (for HEI-2005) and 4 (for original HEI). As might be expected, among the HEI-2005 components, the calories from solid fats, alcoholic beverages, and added sugars score has the strongest correlation with energy, but it was still low ($-.22$). All other components had correlations with an absolute value $\leq .11$, suggesting that energy intake and the scores are independent as desired. The component scores for the original HEI were more highly correlated with energy; the component scores with the strongest negative correlations were the sodium score ($-.69$) and

Table 1. Healthy Eating Index-2005 (HEI-2005) component and total scores for menus exemplifying MyPyramid, the Dietary Approach to Stop Hypertension (DASH) Eating Plan, Harvard's Healthy Eating Pyramid, and the American Heart Association's (AHA) No-Fad Diet

	Food Guide			
Component (maximum score)	**MyPyramid[a]**	**DASH[a]**	**Harvard[b]**	**AHA[c]**
Total fruit[d] (5)	5	5	5	5
Whole fruit[e] (5)	5	5	5	5
Total vegetables[f] (5)	5	5	5	5
Dark green and orange vegetables and legumes[f] (5)	5	5	5	4.9
Total grains (5)	5	4.8	5	5
Whole grains[g] (5)	5	5	5	5
Milk[h] (10)	10	10	0.9	8.7
Meat and beans[i] (10)	10	10	10	10
Oils[j] (10)	10	10	10	10
Saturated fat (10)	10	10	10	10
Sodium (10)	10	10	10	10
Calories from solid fats, alcoholic beverages, and added sugars (20)	20	20	20	20
Total HEI-2001 score (100)	100	99.8	90.9	98.6

[a]Based on a 1-week sample menu.
[b]Based on two 1-week sample menus.
[c]Based on two 1-day sample menus.
[d]Includes 100% juice.
[e]Includes all forms except juice.
[f]Includes legumes only after meat and beans standard is met.
[g]All grain products described as "whole" were assumed to be 100% whole grain.
[h]Includes all milk products, such as fluid milk, yogurt, and cheese, and soy beverages.
[i]Includes legumes only if the meat and beans standard is otherwise not met.
[j]Includes nonhydrogenated vegetable oils and oils in fish, nuts, and seeds.
NOTE: Information from this table is available online at www.adajournal.org as part of a PowerPoint presentation.

the cholesterol score (−.43). Those with the highest positive correlations were the grains (.44), meat (.41), and variety (.39) scores.

The scree plot from the PCA revealed that multiple factors underlie the HEI-2005 and that no one single linear combination of the components of the HEI-2005 accounts for a substantial proportion of the covariation in dietary patterns observed in the NHANES 2001-2002 data (Figure 3).

Correlations between components and their respective total group score for the HEI-2005 are quite low and lower than those of the original HEI. For the HEI-2005, the Cronbach's coefficient α is .43. The component scores most highly correlated with the total score are calories from solid fats, alcoholic beverages, and added sugars (.57) and the fruit components (.43 and .45) (Table 3). Three of the component scores have low negative correlations with the total score, sodium (−.22), milk (−.12), and meat and beans (−.01). The correlations for the other components range from .07 to .26.

For the original HEI, the coefficient α is .28. The component scores with the highest positive correlation with the total score are variety (.40) and fruit (.34). Three component scores are negatively correlated with the total score, sodium (−.31), meat (−.10), and cholesterol (−.02) (Table 4). The correlations for the other components range from .02 to .28.

DISCUSSION

Content validity of the HEI-2005 was supported through a careful review that ensured that the components of the HEI-2005 reflect the key recommendations found in the 2005 Dietary Guidelines. Construct validity was supported by the analyses of exemplary menus, which demonstrated that the HEI-2005 captures the theoretical construct of a high-quality diet, as all the menus received high scores. Although the exemplary menus were not scored according to the original HEI, the expectation is that they also would have scored very high because the menus were moderate in calories, nutritionally adequate, low in saturated fat and sodium, and included a variety of foods.

The HEI-2005 was able to detect substantial differences in the quality of 1-day diets of smokers and nonsmokers, demonstrating concurrent criterion-related validity. The differences in HEI-2005 scores of smokers and nonsmokers were greater than the differences in their original scores. The HEI-2005 also succeeded in uncoupling diet quality and diet quantity, as demonstrated by the low correlation between the total and component scores with energy intake.

The most widely recognized form of reliability is test-retest reliability, which determines whether an index can be expected to yield the same score, time after time, in identical situations. We did not evaluate this type of reliability because the HEI, by definition, will be identical for identical diets that are recalled, recorded, and coded the same way. That is, all sources of test-retest measurement error can be attributed to respondent recall or data collection and processing. Inter-rater reliability is not an issue with the HEI because no judgment is required for scoring once an individual reports his or her food intake.

Table 2. Mean component and total 1-day scores and energy intakes for current smokers and nonsmokers, using the original Healthy Eating Index (HEI) and the Healthy Eating Index-2005 (HEI-2005), adults age 20 years and older, United States, 2001-2002[a]

	Smokers (n=1,022)	Nonsmokers (n=3,386)
Component	**Mean (SE[b])**	**Mean (SE)**
Original HEI		
Total fruit	2.5 (0.2)	4.3 (0.1)*
Total vegetables	5.7 (0.1)	6.4 (0.1)*
Total grains	6.0 (0.1)	6.7 (0.1)*
Milk	4.9 (0.2)	5.6 (0.1)*
Meat (and beans)	6.9 (0.1)	7.0 (0.1)
Sodium	6.2 (0.2)	6.1 (0.1)
Saturated fat	6.8 (0.1)	6.9 (0.1)
Total fat	6.5 (0.1)	6.5 (0.1)
Cholesterol	7.4 (0.1)	7.5 (0.1)
Variety	6.6 (0.1)	7.8 (0.1)*
Total score	59.3 (0.4)	64.8 (0.4)*
HEI-2005		
Total fruit[c]	1.4 (0.1)	2.4 (0.1)*
Whole fruit[d]	1.1 (0.1)	2.2 (0.1)*
Total vegetables[e]	2.7 (0.1)	3.1 (0.0)*
Dark green and orange vegetables and legumes[e]	0.9 (0.1)	1.3 (0.1)*
Total grains	3.9 (0.1)	4.3 (0.0)*
Whole grains	0.6 (0.0)	1.1 (0.0)*
Milk[f]	4.1 (0.2)	4.9 (0.1)*
Meat and beans[g]	7.8 (0.1)	8.2 (0.1)
Oils[h]	5.1 (0.1)	5.6 (0.1)*
Saturated fat	6.1 (0.1)	6.1 (0.1)
Sodium	4.9 (0.1)	4.2 (0.1)
Calories from solid fats, alcoholic beverages, and added sugars	5.9 (0.4)	9.7 (0.2)*
Total score	44.7 (0.6)	53.3 (0.4)*

[a]Excludes pregnant and lactating women. Source of intake data: National Health and Nutrition Examination Survey, 2001-2002.
[b]Standard error.
[c]Includes 100% juice.
[d]Includes all forms except juice.
[e]Includes legumes only after meat and beans standard is met.
[f]Includes all milk products, such as fluid milk, yogurt, and cheese, and soy beverages.
[g]Includes legumes only if the meat and beans standard is otherwise not met.
[h]Includes nonhydrogenated vegetable oils and oils in fish, nuts, and seeds.
*$P<0.01$.

The internal consistency of the HEI-2005 was low, suggesting a lack of association among the component scores. Further, the PCA found no evidence for a single, systematic underlying relationship among all the components. This finding was expected because diet quality, as specified in the 2005 Dietary Guidelines, is comprised of different, independent aspects. Given the multidimensionality of the HEI-2005, more information and insight regarding differences in diet quality can be gained by examining the component scores in addition to the total score.

Correlations between components and the total score indicate how much variance each component contributes to the total score. Thus, variation in the total score is more reflective of the variation observed in those components that have higher correlations with the total score. For example, if the total fruit score had been highly correlated with the total HEI-2005 score, then one could have been comfortable in saying that people with high total HEI-2005 scores are likely to be meeting the standard for fruit consumption. On the other hand, a component with zero correlation with the total score indicates independence, that is, whether a group's total score is high or low is unrelated to its score on the component. In this situation, the component score provides information about a person's diet independent of what the total score is telling us.

The correlations of the component scores with the total score were generally quite low for both the original HEI and the HEI-2005. The correlations indicated that the calories from solid fats, alcoholic beverages, and added sugars and the two fruit components have more influence on the total HEI-2005 score relative to the other HEI components. For the original HEI, the scores were driven by variety, fruit, and sodium. For both versions, fruit was most highly correlated with the total score. The components having correlations with the total score that are $<.4$ may not be adding much information to the total score, but rather provide important, independent information.

As expected, most component scores had a positive correlation with the total HEI-2005 score. Sodium and milk scores, however, had low, negative correlations with the total score ($-.23$ and $-.13$, respectively). For sodium, this reflects how widely it is distributed in foods, both naturally occurring and added in processing and preparation of many foods. The higher the total grains, total vegetables, and meat and beans component scores are, the higher sodium intake is and, therefore, the lower the sodium component score is. The negative correlation of the milk and saturated fat component scores ($-.34$) appears to be the main reason why the milk component is negatively correlated with the total HEI score. The low, negative correlation between the milk score and the total score ($-.13$) reflects the fact that most milk products currently consumed have saturated fat (eg, whole milk and ice cream) and/or are high in sodium (eg, cheese) (21).

An extensive discussion of the strengths and limitations of the HEI-2005 standards and scoring system is presented in a companion article (7). A limitation of the tests of validity and reliability presented here is that these tests may not apply equally to specific ethnic and cultural groups whose dietary patterns are markedly different from the US norm.

Using a Set of Component Scores vs a Total Score

By definition, an index is a single number derived from a series of observations and used as an indicator or measure. For example, the Consumer Price Index (CPI) is a measure of a weighted average of prices of a specified set of goods and services purchased by consumers. As economists monitor the CPI, they also monitor the various market sectors. The CPI could appear to have a flat overall index trend, but that could be hiding the fact, for example, that energy costs had gone down a few percent-

Table 3. Correlations of 1-day Healthy Eating Index-2005 (HEI-2005) component and total scores and energy intake, United States, 2001-2002[a]

Component	Total fruit[b]	Whole fruit[c]	Total vegetables[d]	Dark green and orange vegetables and legumes[d]	Total grains	Whole grains	Milk[e]	Meat and beans[f]	Oils[g]	Saturated fat	Sodium	Calories from solid fats, alcoholic beverages, and added sugars	Total score[h]	Energy
Total fruit[b]	1													
Whole fruit[c]	0.73	1												
Total vegetables[d]	0.06	0.09	1											
Dark green and orange vegetables and legumes[d]	0.12	0.13	0.45	1										
Total grains	0.04	0.06	−0.09	−0.05	1									
Whole grains	0.15	0.18	0.00	0.07	0.24	1								
Milk[e]	0.06	0.08	−0.10	−0.07	0.10	0.10	1							
Meat and beans[f]	−0.03	0.00	0.14	0.16	−0.11	−0.06	−0.24	1						
Oils[g]	−0.04	0.00	0.14	0.05	0.03	0.05	−0.11	0.12	1					
Saturated fat	0.19	0.14	0.06	0.10	0.08	0.11	−0.34	−0.04	−0.03	1				
Sodium	0.06	0.02	−0.27	−0.13	−0.23	−0.02	−0.04	−0.19	−0.08	0.11	1			
Calories from solid fats, alcoholic beverages, and added sugars	0.37	0.33	0.30	0.24	0.23	0.27	0.04	0.21	0.28	0.22	−0.28	1		
Total score[h]	0.43	0.45	0.18	0.26	0.07	0.26	−0.12	−0.01	0.10	0.14	−0.22	0.57	1	
Energy	−0.10	−0.09	−0.05	−0.05	−0.06	−0.10	0.00	0.08	0.06	−0.11	0.08	−0.22	−0.14	1

[a]Note: Excludes children under age 2 years, breast-fed children, and pregnant and lactating women. Source of intake data: National Health and Nutrition Examination Survey, 2001-2002.
[b]Includes 100% juice.
[c]Includes all forms except juice.
[d]Includes legumes only after meat and beans standard is met.
[e]Includes all milk products, such as fluid milk, yogurt, and cheese, and soy beverages.
[f]Includes legumes only if the meat and beans standard is otherwise not met.
[g]Includes nonhydrogenated vegetable oils and oils in fish, nuts, and seeds.
[h]Total HEI-2005 score minus specified component.

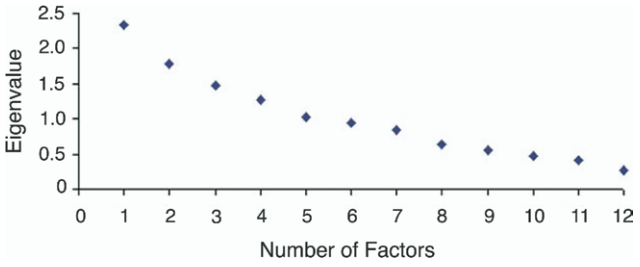

Figure 3. Scree plot from principal component analysis (PCA) of the Healthy Eating Index-2005 (HEI-2005) showing the amount of variance accounted for by each of the principle components or factors Source of intake data: National Health and Nutrition Examination Survey, 2001-2002. Note: The optimal number of factors is determined by looking for places where the curve formed by connecting the dots starts to form a flat, horizontal line, here between five and eight factors. The eigenvalue of >1 also indicates at least five factors. Thus, the PCA provides evidence that no one single linear combination of the components of the HEI-2005 accounts for a substantial proportion of the covariation in dietary patterns. NOTE: This figure is available online at www.adajournal.org as part of a PowerPoint presentation.

age points and other costs, such as housing and medical care, had gone up a few points.

Just as the CPI reflects a market basket of prices, the HEI-2005 was designed to reflect multiple aspects of diet quality. As with the other indexes, a lack of difference in the total HEI score over time, among groups or among individuals, could mask important differences among the components. Nonetheless, there are situations where the total score can be instructive. It provides a summary assessment across the components and can be used in much the same way as the other indexes have been. Specifically, the total score is useful in distinguishing very high scoring diets from very low scoring diets, as in epidemiological dietary patterns analyses that model disease risk among those in the highest quintile compared with those in the lowest quintiles of dietary quality.

Using Labels to Describe Diets with Varying Scores

The fact that mid-range total scores can indicate a range of diet quality across the various components suggests that ratings (such as good, fair, or poor) or grades (such as A, B, C, or D) to describe the mid-ranges would be equally difficult to interpret. A "fair" overall assessment could mean "fair" on all components or "outstanding" on some and "poor" on others. For this reason and because of the potential differences among component scores, as mentioned above, the rating or grading of diets according to total HEI score is not recommended.

Comparison to Other Indexes

Like other diet-quality measures that have been developed, HEI-2005 has multiple components (nutrients and/or foods) that are summed to create a total score to reflect a level of diet quality based on predefined dietary standards. The HEI-2005 differs from the original HEI primarily in assessing the quality of the diet on a density basis and introducing new components for oils; whole fruit; dark green and orange vegetables and legumes; whole grains; and calories from solid fats, alcoholic beverages, and added sugars (7).

These characteristics also differentiate the HEI-2005 from other indexes. The earliest dietary scoring systems, for example, the Mean Adequacy Ratio and the Index of Nutritional Quality, used only nutrients (22,23). The Diet Quality Index (24) was the first attempt at a more comprehensive assessment of diet quality, including foods as well as nutrients. The revised Diet Quality Index (25) and the original HEI have been modified for use with different populations, including pregnant women (26), children and adolescents (27,28), and people living in China (29). The Alternate Healthy Eating Index (30) and the Mediterranean Diet Score (31) were developed based on other food guidance systems, Harvard's Healthy Eating Pyramid and the Mediterranean diet, respectively. The Dietary Guidelines for Americans Adherence Index differs from the HEI-2005 in that intakes of some components that are higher than recommended levels can get scores that are equal to intakes that fall short of recommendations (32).

The predictive criterion validity of the HEI-2005 was demonstrated in a prospective cohort study of nearly 500,000 Americans that compared the how the HEI-2005, the Alternate Healthy Eating Index, the Mediterranean Diet Score, and the Recommended Food Score are associated with the colorectal cancer (33). Scores for all indexes predicted a similar risk among men, while only HEI-2005 scores were positively associated with decreased risk among women.

CONCLUSIONS

The density standards developed for use in the HEI-2005 succeeded in uncoupling diet quality from diet quantity. The HEI-2005, accordingly, assesses the mix of foods eaten, and mitigates, to some degree, the effects of day-to-day variability in amounts of food eaten. Furthermore, if one assumes that all food groups are equally incorrectly reported, then the effects of under- or overreporting are also mitigated; however, the extent to which this is true is unknown.

There is strong evidence that the HEI-2005 is a valid measure of diet quality, as demonstrated by its fidelity to the key recommendations of the 2005 Dietary Guidelines, its ability to distinguish between groups with known differences in diet quality, and the independence of diet quality and diet quantity as measured by energy intake. The PCA and reliability analysis confirmed the multidimensional nature of diet quality and that the individual components of the HEI provide additional insight to that of the total score. The HEI-2005 has a variety of potential purposes. It is used by the US Department of Agriculture for population monitoring (6) and has been used by the National Cancer Institute in epidemiologic research (29). Other potential applications include evaluation of nutrition interventions, economic research, and other types of research.

Possibilities for further research include additional validity testing. For example, further research could examine how well the HEI-2005 performs across ethnic and cultural groups whose dietary patterns may differ mark-

Table 4. Correlations of 1-day original Healthy Eating Index (HEI) component and total scores and energy intake, United States, 2001-2002[a]

Component	Fruit	Vegetables	Grains	Milk	Meat (and beans)	Sodium	Saturated fat	Total fat	Cholesterol	Variety	Total score[b]	Energy
Fruit	1											
Vegetables	0.08	1										
Grains	0.11	0.09	1									
Milk	0.11	0.04	0.27	1								
Meat (and beans)	0.01	0.27	0.11	−0.02	1							
Sodium	0.02	−0.33	−0.45	−0.24	−0.43	1						
Saturated fat	0.17	0.02	0.04	−0.32	−0.06	0.12	1					
Total fat	0.19	−0.11	0.05	−0.04	−0.20	0.15	0.65	1				
Cholesterol	0.02	−0.15	−0.08	−0.09	−0.41	0.38	0.22	0.24	1			
Variety	0.38	0.47	0.36	0.35	0.38	−0.41	−0.02	−0.02	−0.22	1		
Total score[b]	0.34	0.11	0.15	0.02	−0.10	−0.31	0.24	0.28	−0.02	0.40	1	
Energy	0.05	0.29	0.44	0.30	0.41	−0.69	−0.09	−0.08	−0.43	0.39	0.09	1

[a]Note: Excludes children under age 2 years, breast-fed children, and pregnant and lactating women. Source of intake data: National Health and Nutrition Examination Survey, 2001-2002.
[b]Total HEI score minus specified component.

edly from the US norm. Researchers are encouraged to further evaluate the predictive and concurrent criterion validity of the HEI-2005 and to further compare its efficacy with that of other indexes of diet quality. This type of research could add to the evidence base for future editions of the Dietary Guidelines for Americans.

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